XV. *Theory of the inverse Ratio which subsists between the Respiration and Irritability, in the Animal Kingdom.* *By* MARSHALL HALL, *M.D. F.R.S.E. M.R.I. &c. &c. Communicated by* J. G. CHILDREN, *Esq. Sec. R.S.*

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THE object of the investigation, of which the present paper details the principles, is to trace a peculiar law of the animal economy, through the various series, forms and conditions of animated being. This law may be announced in the following terms:

The quantity of the Respiration is inversely as the degree of the Irritability of the muscular fibre.

It will be necessary, in the very first place, to define the terms which I am about to employ. The expression inverse ratio is not used in its strict mathematical sense, but merely to designate the general fact, that, in cases in which the quantity of respiration is great, the degree of irritability is low; and that in cases in which the quantity of respiration is small, the degree of irritability is high. By the quantity of respiration, I mean the quantity of oxygen gas consumed, or exchanged for carbonic acid, in a given time, by the animal confined in atmospheric air. I have used the term irritability in the sense in which it is employed by GLISSON and HALLER,—to designate that peculiar property of the muscular fibre by which it contracts on the application of an appropriate stimulus; and I consider that muscle the most irritable which, cæteris paribus, contracts most and longest upon the application of the least degree of such stimulus. HALLER's definition of the term is very similar *. It must be confessed that the word irritability only expresses one half of the property or function of the muscular fibre,—its susceptibility to the influence of irritants or stimuli; the term contractility is equally defective,—expressing

* Mémoires sur la Nature sensible et irritable des Parties du Corps animal. Tome i. pp. 7—8, 75.

only the other half of that function, viz. the effect of that susceptibility under the actual influence of stimuli. The designation irrito-contractility would express the whole phenomena.

Organic life appears to result from the impression of stimuli upon parts endued with irritability. The principal stimuli in nature, are air, food, and heat; the principal and corresponding organs of irritability are the heart, the stomach, and the muscular system in general.

The animal series consists of beings variously modified by the varied degree of irritability, and by the varied quantity of stimulus. Throughout the whole these observe an inverse ratio. The bird tribes and the mammalia are characterized by great respiration, whilst the irritability of the muscular fibre is low; the reptiles, the batrachia and the fish tribes, on the other hand, are endued with a high degree of irritability, and little respiration. The higher parts of the zoological series consist of animals chiefly characterized by the appropriation of a great quantity of stimulus; the lower, by the high degree of irritability of the muscular fibre. The former are animals of stimulus—of activity; the latter are animals of irritability.

The due actions of life, in any part of the zoological series, appear to depend upon the due ratio between the quantity of atmospheric change induced by the respiration, and the degree of irritability of the heart: if either be unduly augmented, a destructive state of the functions is induced; if either be unduly diminished, the vital functions languish and eventually cease. If the bird possessed the degree of irritability of the reptile tribes, or the latter the quantity of respiration of the former, the animal frame would soon wear out. If, on the contrary, the bird were reduced to the quantity of respiration appro priate to the reptile, or the latter to the degree of irritability which obtains in the former, the functions of life would speedily become extinct. Various deviations from the usual proportion between the respiration and the irritability, however, occur, but there is an immediate tendency to restore that proportion; increased stimulus exhausts or lowers the degree of irritability, whilst diminished stimulus allows of its augmentation. The alternations between activity and sleep afford illustrations of these facts.

Changes in anatomical form in the animal kingdom present other illustrations of the law of the inverse proportion of the respiration and irritability.

The egg, the fœtus, the tadpole, the larva, &c. are respectively animals of lower respiration, and of higher irritability, than the same animals in their mature and perfect state. Changes in physiological condition also illustrate the same law. The conditions of lethargy, and of torpor, present examples of lower respiration, and of higher irritability, than the state of activity.

It may be remarked that whilst changes in anatomical form are always from lower to higher conditions of existence, changes in the physiological condition are invariably from higher to lower.

These views are further illustrated by a reference to the quantity of stimulus and the degree of irritability of each of the parts and organs of the animal system. But it is to the quantity of respiration, and the degree of irritability of the heart, that our attention is to be principally directed at this time. The oxygen of the atmospheric air is the more immediate and essential stimulus of this organ. Taken up in respiration, it is brought into contact with the heart, by means of the blood, which may be considered as the carrier of this stimulus, as it is of temperature and nutriment, to the various parts of the system. As oxygen is the principal stimulus, the heart is the principal organ of irritability, in all the vertebrated animals; if the contact of oxygen be interrupted, all perish in a greater or less period of time.

The extraordinary differences which exist in animals which occupy different stations in the zoological scale, have long excited the attention of naturalists. Nor have the differences which obtain in the various ages and states of its existence, in the same animal, escaped the attention of the physiologist. A similar remark applies to that singular state of existence and of the functions of life, designated hybernation. But it appears to me that a sufficiently comprehensive view has not been taken of the subject, and that many facts, with their multitudinous relations, still require to be determined.

I. *Of the Pneumatometer.*

The principal of these facts is that of the quantity of respiration. This is greater in proportion as the animal occupies a higher station in the zoological scale, being, among the vertebrated animals, greatest of all in birds, and lowest in fishes; the mammalia, the reptiles, and the amphibia occupy intermediate stations. The quantity of respiration is also remarkably low in the very

young of certain birds which are hatched without feathers, and of certain animals which are born blind; and in hybernation it is almost extinct.

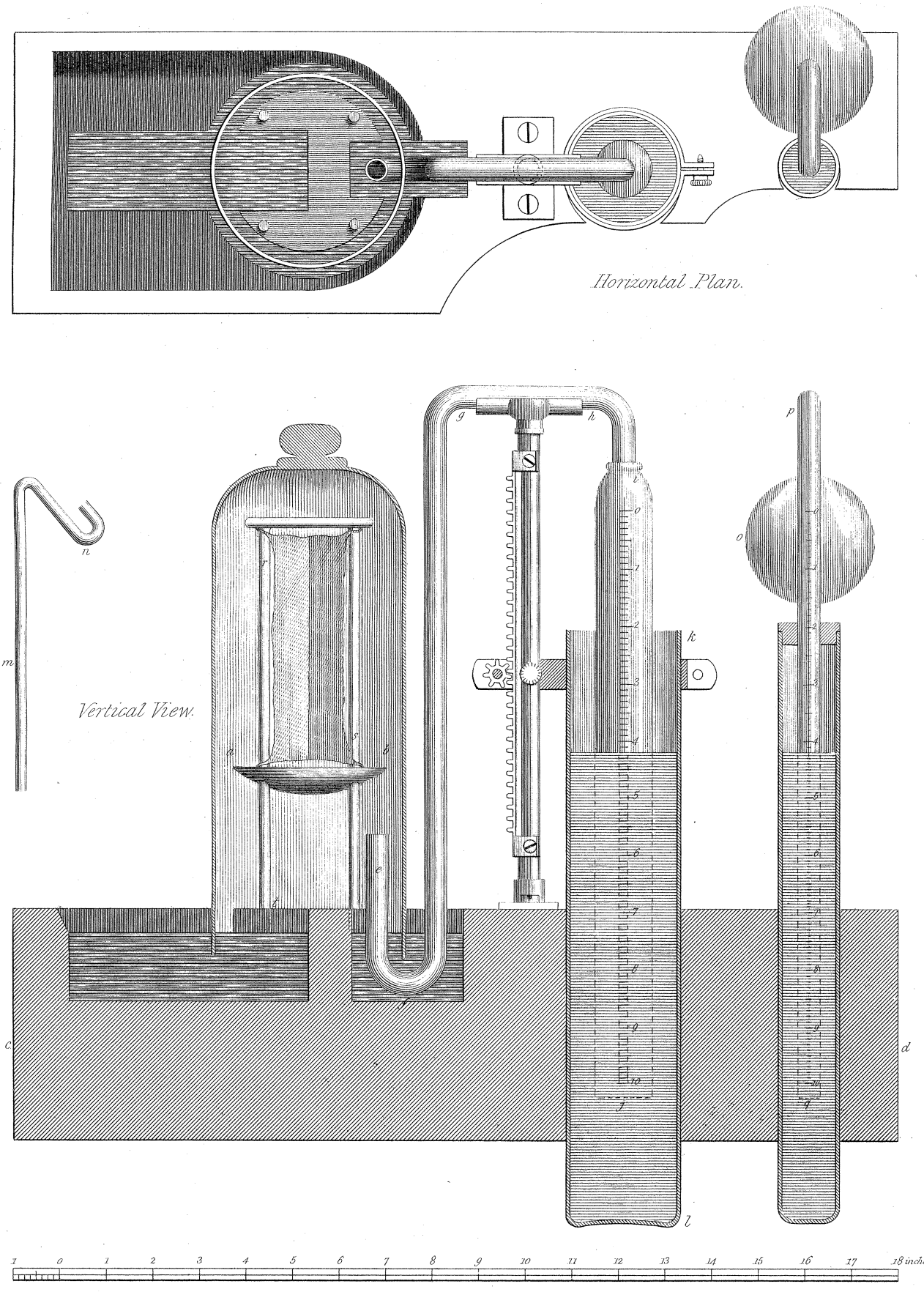
To ascertain the quantity of respiration in any given animal, with extreme minuteness, was a task of great difficulty. It was still more difficult to determine this problem, so as to represent the quantities of respiration in the different kinds, ages, and states of animals, in an accurate series of numbers. The changes induced in a given volume of air made the subject of experiment, by changes in the temperature and pressure of the atmosphere, and by variations in the height of the fluid of a pneumatic trough, which it is so difficult to appreciate minutely; the similar changes induced by the humidity of expired air, and by the heat of the animal itself, were so many and complicated, that it appeared almost impossible to arrive at a precise result. These difficulties, in fine, were such as to lead one of the first chemists of the present day to give up some similar inquiries in despair.

Fortunately I have been enabled to devise an apparatus which reduces this complex problem to the utmost degree of simplicity. I now beg the indulgence of the Society whilst I give a detailed description of its construction and mode of operation.

This apparatus, which I shall designate the *Pneumatometer*, consists of a glass jar *a b* (Plate XI.) inverted in a mercurial trough *c d*, so grooved and excavated, as accurately to receive the lower rim of the jar and the lowest part of the tube *e f g*, and also to admit of the animal which is made the subject of experiment, being withdrawn through the mercury. This jar communicates, by means of the bent tube *e f g h*, with the gauge *i j*, which is inserted into a larger tube, *k l*, containing water. A free communication between the jar and the external air is effected and cut off, at any time, by introducing and withdrawing the little bent tube *m n*, placing the finger upon the extremity *m*, whilst the extremity *n* is passed through the mercury.

If the jar be of the capacity of one hundred cubic inches, the gauge is to contain ten, and to be graduated into cubic inches and tenths of a cubic inch; so that each smallest division shall be the thousandth part of the whole contents of the jar.

Attached to the same mercurial trough is placed a little apparatus, *o p*, termed an *Aërometer*, and consisting of a glass ball *o*, of the capacity of ten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cubic inches, communicating with a tube *p q*, bent at its upper part, of the capacity of one cubic inch, divided into tenths and hundredths, and inserted into a wider tube containing water, precisely in the manner of the gauge *i j*. In order to secure the exact proportion between the capacity of the pneumatometer and that of the aërometer, it is only necessary to add more or less of mercury to the trough.

The whole apparatus is inclosed in a glazed frame so as entirely to obviate the influence of partial currents of air. It is plain that changes in external temperature and pressure will affect both these parts of the apparatus equally; and that the fluids in the gauge *i j*, and in the tube *p q*, will move pari passu. It is therefore only necessary to compare them, and to take the difference, for the real alteration in the quantity of the gas in the jar.

Previously to noticing this difference, the fluids in the outer and inner tubes are to be brought accurately to the same level, by raising or depressing the outer tube *k l*, and the inner one *p q*.

In order that the air within the jar and that in the aërometer may be in the same state of humidity, a little water is introduced into the ball *o* of the latter.

When the animal is to be removed, the fluid in the inner and outer tubes of the gauge are to be brought to a precise level; the animal is then to be withdrawn through the mercury, by a cord attached to the little net or box in which it is secured; a quantity of fluid will immediately rise in the inner tube, *i j*, equal to the bulk of the animal; the bent tube, *m n*, is now to be passed through the mercury into the jar so as to effect a communication with the atmospheric air; a portion of air equal to the bulk of the animal rushes into the jar, whilst the fluids in the gauge regain their level.

To avoid the error which would arise from the influence of the temperature of the animal upon the air within the jar of the pneumatometer, the first observation of the degree upon the gauge must be made the instant the experiment is begun, and before the temperature of the animal can have been communicated to it; and the last, so long after the animal has been withdrawn as to allow of its restoration to the temperature of the atmosphere.

In this way all calculations for the varied temperature and pressure of the external air, for augmented humidity and temperature of the air of the pneumatometer, and for the changes in the height of the fluid of the trough, are at once disposed of in a manner the most accurate and simple.

It now remains to determine the quantity of change induced upon the air of the pneumatometer, by the respiration of the animal. Two views may be taken of this change; that of Messrs. Allen and Pepys, that the oxygen which disappears is replaced by a precisely equal bulk of carbonic acid; or that of M. Edwards, that there is generally an excess of the oxygen which disappears over that of the carbonic acid evolved. In either case the quantity of respiration is ascertained by the gauge of the pneumatometer in the following manner. A frame made of glass rods, *r s*, is placed within the jar *a b*, suspending portions of calico, imbued with a strong solution of pure potassa, and provided with a small dish of wood, so as to prevent the caustic liquid from dropping upon the animal beneath. By this means the carbonic acid is removed as it is evolved, or after the animal is withdrawn. The rise of the fluid in the gauge of the pneumatometer gives the quantity of oxygen which disappears,—whether this be entirely exchanged for carbonic acid, or only partly exchanged for carbonic acid, and partly absorbed,—and denotes the precise quantity of the respiration.

The question itself, of the entire or partial exchange of the oxygen gas which disappears, for carbonic acid gas evolved, is at once determined by employing the same apparatus without the solution of potassa: in the entire exchange, there is no alteration in the bulk of the air of the pneumatometer; in the case of a partial exchange, the alteration in the bulk of the air gives the precise excess of oxygen gas which disappears, over the quantity of carbonic acid evolved.

But this question, and that of the absorption and evolution of nitrogen, with the influence of night and day, of season, &c. are reserved for a future stage of this inquiry.

It is important that the animal should be left for a considerable time in the very situation in which it is to remain during the experiment, before that experiment is begun, and before the jar is placed over it. In this manner the effect of timidity or restlessness is allowed to subside, and prevented from mingling with that of the natural state of the respiration. A bit of cork must also be attached to the mercurial trough, so as to float upon the mercury at *t*, and prevent the disturbing effect of the contact of this fluid with the animal.

It is also well, after having placed the jar in the groove of the mercurial

trough, to pour a little water over the mercury exterior to the jar. The apparatus is thus rendered perfectly air-tight, which is not always effected by the mercury alone.

By means of this apparatus we readily and accurately determine the quantity of the respiration of any given animal, in any given circumstances.

II. *Of the Measure of the Irritability.*

The problem to be next determined is that of the degree of irritability of the muscular fibre, and especially of the heart. This question is beset with scarcely fewer or less difficulties than that of the quantity of respiration, whilst it involves far greater errors and more discrepancy of opinion on the part of physiologists.

Even Baron CUVIER* has fallen into these errors. It will be shortly demonstrated that the degree of irritability is, in every instance, inversely as the quantity of respiration. Yet M. CUVIER, in a remarkable paragraph, states the very contrary, and even speaks of that which is the exhauster, as the repairer, of the irritability; whilst, on the other hand, he makes statements which appear to me at variance with this very opinion. In the Anatomie Comparée (tome i. p. 49), this celebrated writer observes, "Les expériences modernes ont montré qu'un des principaux usages de la respiration est de ranimer la force musculaire, en rendant à la fibre son irritabilité epuisée." See also tome iv. p. 301. Similar observations are made in M. CUVIER's more recent work, the Règne Animal: "C'est de la respiration que les fibres musculaires tirent l'énergie de leur irritabilité." tome i. p. 57. 2me edit. "C'est la respiration qui donne au sang sa chaleur, et à la fibre la susceptibilité pour l'irritation nerveuse." tome ii. p. 1. On the other hand, speaking of the mollusca, (tome iii. p. 3.) M. CUVIER observes of those animals of low respiration, "L'irritabilité est extrême dans la plupart." The same term is, in fact, used in two distinct senses, in these paragraphs.

No further proof can be necessary of the extreme vagueness and incorrect-

* Since this paper was read, science has experienced an irreparable loss in the death of this great man. I will not imagine that my comments upon what I conceive to be an error in his writings will be misinterpreted. No one can look upon CUVIER's labours with more sincere admiration than myself.

ness of the prevailing notions and expressions of physiologists in regard to this subject. All this will appear still more extraordinary, when the law, that the quantity of respiration and the degree of the irritability are, in fact, inverse throughout all the series, stages, and states of animated being, is clearly established.

It is well known that the irritability of the heart and of the muscular fibre in general, is greater in the mammalia than in birds, and in reptiles and the amphibia than in the mammalia, whether we judge of it by the force and duration of the beat of the heart, exposed to the stimulus of the atmospheric air, or by the contractions of the other parts of the muscular system. Now this is precisely the order of the quantity of respiration in these animals, as ascertained by the pneumatometer, inverted. It is essential, in accurately determining the question of the irritability of the muscular fibre, to compare animals of the same class inter se; birds and the mammalia, reptiles and the amphibia, fishes, the mollusca, &c. must be compared with each other, both generically and specifically. It is especially necessary to compare the warm-blooded, the cold-blooded, the air-breathers, and the water-breathers, in this manner. However the different classes may differ from each other, there are differences in some of the species of the same class, and especially that of fishes, scarcely less remarkable.

Great differences in the duration of the beat of the heart, are observed in the fœtal, early, and adult states of the higher animals; this duration being greatest in the first, and least in the last of these conditions. The order of the quantity of respiration is inverse.

The law of the irritability being inversely as the respiration, obtains even in the two sides of the heart itself, in the higher classes of animals. The beat of the heart removed from the body, does not cease at the same time in the walls of all its cavities, or of its two sides: but, as HARVEY observes, "primus desinit pulsare sinister ventriculus; deinde ejus auricula; demum dexter ventriculus; ultimo (quod etiam notavit GALENUS) reliquis omnibus cessantibus et mortuis, pulsat usque dextra auricula*."

Even in this case the irritability is greatest in the part in which the respiration is least.

* Opera Omnia, Collegio Medicorum Londinensi edita, 1766, p. 28.

It was shown by Hook, in the early days of the Royal Society*, that if, the respiration being suspended, an animal appeared to be dying, the beat of the heart and the signs of life were speedily restored, on performing artificial respiration, or even by forcing air through the trachea, bronchia, and pulmonary air-cells and allowing it to escape through incisions made through the pleura.

It was, in the next place, clearly shown by Goodwyn, in one of the most beautiful specimens of physiological inquiry in any language†, that in suspended respiration, it is the left side of the heart which first ceases to contract, the right side still continuing its function for several minutes, until the supply of blood may be supposed to fail.

The facts detailed by Harvey had shown that the left side of the heart was endued with less irritability than the right; the experiment of Hook, that respiration restored the action of the heart, if it had previously ceased; that of Goodwyn, that this cessation and restoration of functions were observed in the left side of the heart. It was obvious, on the other hand, that the respiration belongs, as it were, to the left side of the heart.

It appears plainly deducible from these facts, that in circumstances and structures the most similar, the respiration is accurately inversely as the irritability.

For the sake of a comparison with the hybernating animal, the object of which will be explained hereafter, I thought it right to repeat this experiment.

Before I proceed to detail the result, I may just describe an easy method of performing that part of it which consists of artificial respiration. A quill is firmly fixed in the divided trachea; a small hole is then cut into that part of the quill which is external; Read's syringe is then adapted to the other end of the quill. At each motion of the piston downwards, the lungs are distended; whilst the piston is raised, the air escapes through the opening in the quill, producing expiration. The experiment, therefore, only requires the common action of the syringe.

The experiment itself answered my expectation. During the cessation of

* Phil. Trans. vol. ii.

† On the Connexion of Life with Respiration: London, 1788, pp. 72, 82 note.

respiration, the left ventricle ceased to beat, the right ventricle retaining its function; on renewing the respiration, the left ventricle resumed its beat. It appears from this experiment, that from want of a degree of irritability equal to that of the right ventricle, and its own proper stimulus of arterial blood, the left ventricle ceased its contractions. The function of the right ventricle must soon cease in consequence, from want of a supply of blood.

These facts prove that arterial blood is the necessary stimulus of the left side of the heart, its irritability being low; but that venous blood is a sufficient stimulus of the right, from its higher irritability: the phenomena plainly flow from the law, that the quantity of respiration and the degree of irritability, observe an inverse ratio to each other, and from the facts on which that law is founded. In this double sense, besides that of distinct cavities, the mammalia have, therefore, two hearts; and as the highly aerated blood of the left is the peculiar property of birds and the mammalia, so the highly irritable fibre of the right may be compared to that of the heart of reptiles and the fishes.

Except for the objection to new terms, the left side of the heart might be termed arterio-contractile, and the right veno-contractile; the first being stimulated by arterial, the second by venous blood.

It is quite obvious that the heart will bear a suspended respiration better, the more nearly its irritability approaches to that which may be designated veno-contractile. *The power of bearing a suspended respiration thus becomes a measure of the irritability.* It is expressed, numerically indeed, by the length of time during which the animal can support a suspended respiration; a conclusion of the highest degree of importance in the present inquiry.

Birds die almost instantly on being submerged in water; the mammalia survive about three minutes, the reptiles and the batrachia a much greater length of time.

The unborn fœtus, the young animal born with the foramen ovale open, the reptile, the mollusca, having all a state of the heart approaching to the veno-contractile, bear a long-continued suspension of the respiration, compared with the mature animal of the higher classes.

But the most remarkable fact deducible from this reasoning is the following: if such a case existed as that of the left side of the heart being nearly or absolutely veno-contractile, such an animal would bear the indefinite suspen-

sion of respiration such an animal would not drown though immersed in water. Now there is precisely such a case. It is that of the hybernating animal. It will be shown in the subsequent paper, that in the state of perfect hybernation the respiration is nearly suspended; the blood must, therefore, be venous. Yet the heart continues to contract, although with a reptile slowness. The left ventricle is, therefore, veno-contractile, and in this sense, in fact, sub-reptile. The case forms a sole exception to the law pointed out by HARVEY, that the left ventricle ceases to contract sooner than the right. If in the hybernating animal the left ventricle does cease to beat sooner than the right, it is only in so slight a degree as to be referred to the greater thickness of its parietes, and the slight degree in which respiration still remains. It is obvious that the foregoing statement must be taken with its due limitations. Venous blood is unfit for the other animal purposes, even though it should stimulate the heart to contraction.

Another mode of determining the degree of irritability, is the application of stimuli, as galvanism. A muscular fibre endued with high irritability, as that of the frog, and the galvanic agency are mutually tests of each other*.

A third criterion and measure of the irritability is afforded by the influence of water at temperatures more or less elevated, in inducing permanent contraction of the muscular fibre.

There are two other properties of animals which depend upon the varied forms of the inverse ratio which exists between the respiration and the irritability. The first is *activity*, the second, *tenacity of life*.

The activity, which, I believe, M. CUVIER has confounded with the irritability, is generally directly proportionate to the respiration, and intimately depends upon the condition of the nervous system resulting from the impression of a highly arterial blood upon its masses, and not upon the degree of irritability of the muscular fibre. It is the pure effect of high stimulus.

To show that M. CUVIER has blended the idea of the irritability of the muscular fibre with that of the activity of the animal, it is only necessary to recur to the passages already quoted from that author, and to adduce the observations

* BOSTOCK on Galvanism, pp. 4, 14.

with which they are connected. "On vient de voir à quel point les animaux vertébrés se ressemblent entre eux; ils offrent cependant quatre grandes subdivisions ou classes, caractérisées par l'espèce ou la force de leurs mouvements, qui dépendent elles-mêmes de la quantité de leur respiration, attendu que c'est de la respiration que les fibres musculaires tirent l'énergie de leur irritabilité *."
"Comme c'est la respiration qui donne au sang sa chaleur, et à la fibre la susceptibilité pour l'irritation nerveuse, les reptiles ont le sang froid, et les forces musculaires moindres en totalité que les quadrupèdes, et à plus forte raison que les oiseaux; aussi n'exercent-ils guère que les mouvements du ramper et du nager; et, quoique plusieurs sautent et courent fort vite en certains moments, leurs habitudes sont généralement paresseuses, leur digestion excessivement lente, leurs sensations obtuses, et dans les pays froids ou tempérés, ils passent presque tous l'hiver en léthargie †."

It is extraordinary that M. CUVIER should have associated the elevated temperature of the blood with a high irritability of the muscular fibre, when they are uniformly separated in nature, and are, indeed, absolutely incompatible in themselves. The muscular fibre of the frog is so irritable, that it would instantly pass into a state of rigid and permanent contraction, if bathed with a fluid of the temperature of the blood of birds ‡.

The same confusion of ideas on the subject of the activity of the animal and the irritability of the muscular fibre prevails, I believe, amongst our own physiologists; at least, in conversation with two, who may rank amongst the first, I found that they had uniformly considered the respiration and the irritability to be directly, instead of inversely, proportionate to each other.

That singular and interesting property of the lower orders of animals termed tenacity of life is, on the other hand, distinctly associated with a high degree of irritability of the muscular fibre. This property may be defined as consisting of the power of sustaining the privation of respiration, the privation of food, various mutilations, divisions, &c. It is greater as we descend in the zoological scale. As activity depends upon the presence and condition of the spino-cerebral masses acted upon by arterial blood, tenacity of life depends upon the diminution or absence of these masses and of this highly arterialized blood,

* Le Règne Animal, tome i. pp. 56, 57. 2me edit. † Ibid. tome ii. pp. 1, 2. 2me edit.
‡ See An Essay on the Circulation, chap. vii. pp. 180, 181.

being greatest of all in those animals which approach a mere muscular structure. Almost the sole vital property then remaining is the irritability; and this property does not immediately suffer from division.

It is possible to reduce some of the reptile tribes to a state approaching that of animals still lower in the scale, by removing, by very slow degrees, successive portions of the nervous masses. This is most readily done in animals in which the respiration is already low, and the irritability high, as in the fœtus, in the very young animal, in the reptile, &c., as in the experiments of LEGALLOIS*, M. SERRES†, myself‡, &c.

There is, even in animals most tenacious of life, one kind of mutilation—one kind of injury not well borne. As the blood is in its lowest condition of stimulus, it cannot be withdrawn with impunity; frogs even soon perish if their blood be allowed to flow. As the irritability, on the other hand, is high, certain stimuli, as galvanism, slightly elevated temperatures, &c. are speedily fatal. The batrachia are promptly destroyed by immersion in water of a temperature of 108° of FAHR., and some fish and crustacea perish in great numbers under the influence of a thunder-storm. It is a singular fact, that the fish alone, whose food is found amongst animals of a high irritability, should possess an electrical organ for the destruction of its prey.

Having stated the law of the inverse ratio of the quantity of respiration, and of the degree of irritability of the muscular fibre, especially in the heart, I purpose to trace it, by a series of observations, through the zoological scale, and in the different stages and states of animal existence. This inquiry will be followed by an investigation into the quantity of respiration, in different temperatures and seasons, in animals which retain, and animals which lose their temperature; it is obvious, à priori, that the former must have a lower respiration in the elevated temperatures of summer than in winter, whilst the irritability, and with it the power of supporting the privation of air, will observe an inverse ratio; in the latter, it is probable that other laws prevail.

* Experiences sur le Principe de la Vie.

† Anatomie Comparée du Cerveau, tome ii. p. 224.

‡ Essay on the Circulation, chap. iii. § 1.

A particular object which I have in view is to construct accurate Tables of the quantity of respiration and the degree of irritability, which cannot fail to have many important applications in physiology. They will especially afford many explanations of the facts detailed in the extraordinary works of LEGALLOIS and M. EDWARDS, as I shall have occasion to point out particularly hereafter. The facts in regard to the irritability, ascertained by NYSTEN* and MANGILI†, insulated and useless hitherto, will assume a new and high degree of importance. The law of the inverse ratio which subsists in the animal kingdom between the respiration and the irritability of the muscular fibre, which admits of being extended so as to include all stimuli, appears to me, indeed, to constitute a chain which links together all the phenomena of the animal economy. I believe it to be the most general and inclusive in physiology.

* Recherches de Physiologie, sect. iv.

† Annales du Museum, tome x. p. 434.